Wire Scanner and downstream magnets

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2007/06/07

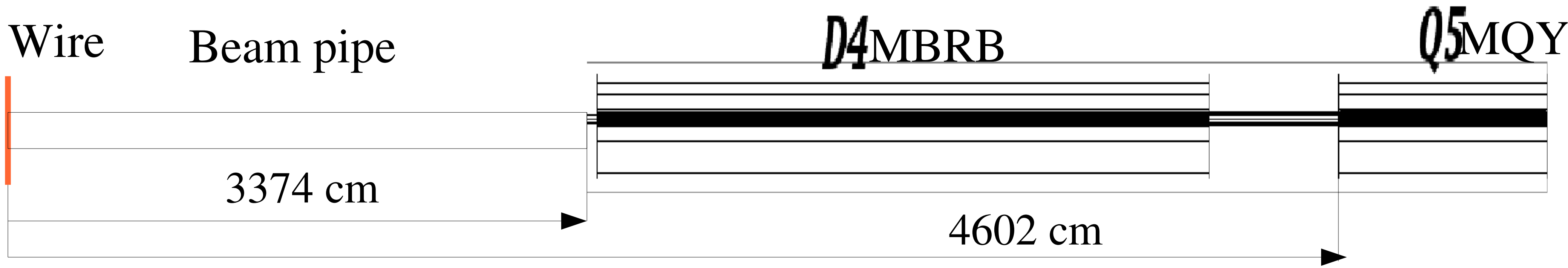
Overview

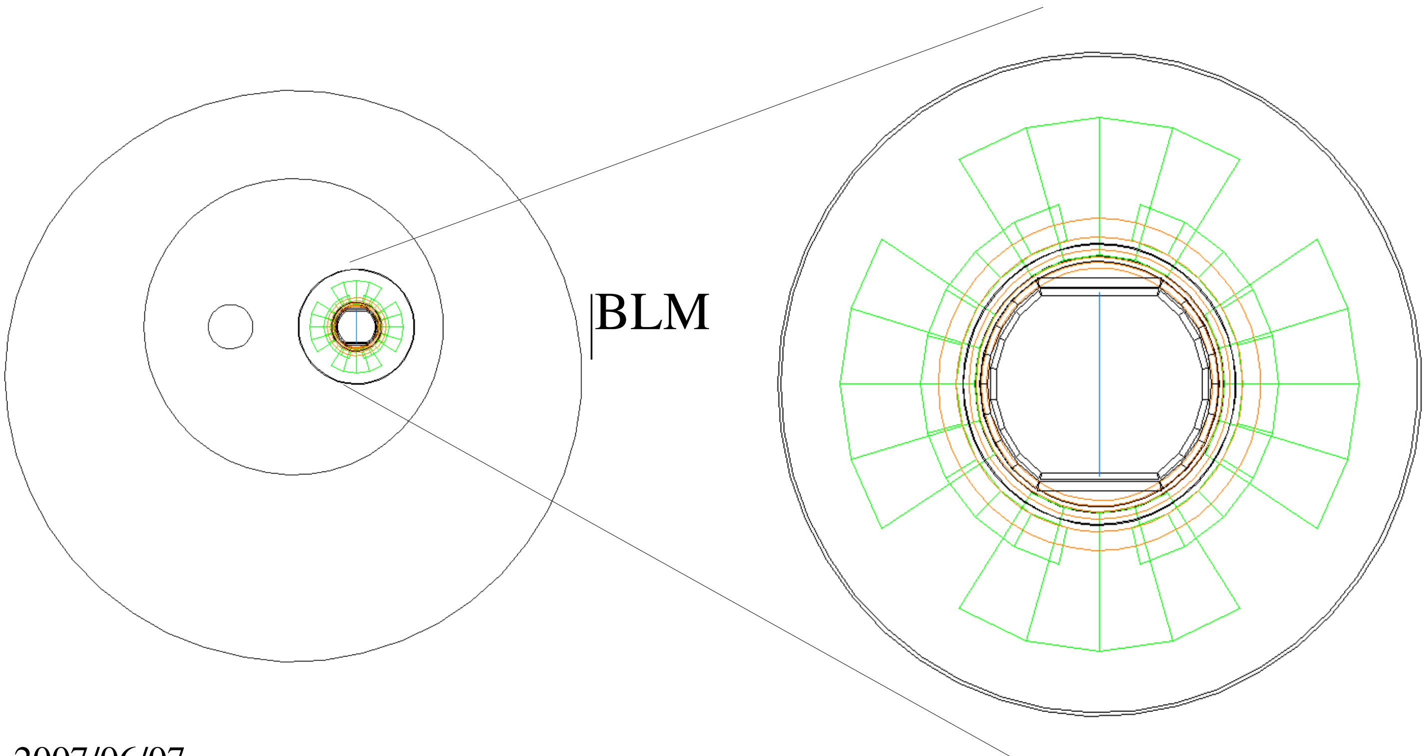
- Previous estimations
- Simulated geometry
- Statistics
- Placement of scintillators
- Cascades in magnet coils (binning)
- Maximal beam intensity
- Errors and approximations

Previous estimations

- J.Bosser, C.Bovet, “Wire scanners for LHC” LHC Project Note 108 (1997): “..no superconducting dipole is expected to be located in the 40 m downstream of a wires scanner...”; limit from wire overheating is about 12% of nominal beam at 7 TeV
- M. Lebat, E. Petit - summer students (2005 and 2006), who started this work

Geometry





Coils are divided into small cells in (in r,φ,z) which energy is measured.

Typically:

$2\text{-}3 \cdot 10^5$ cells

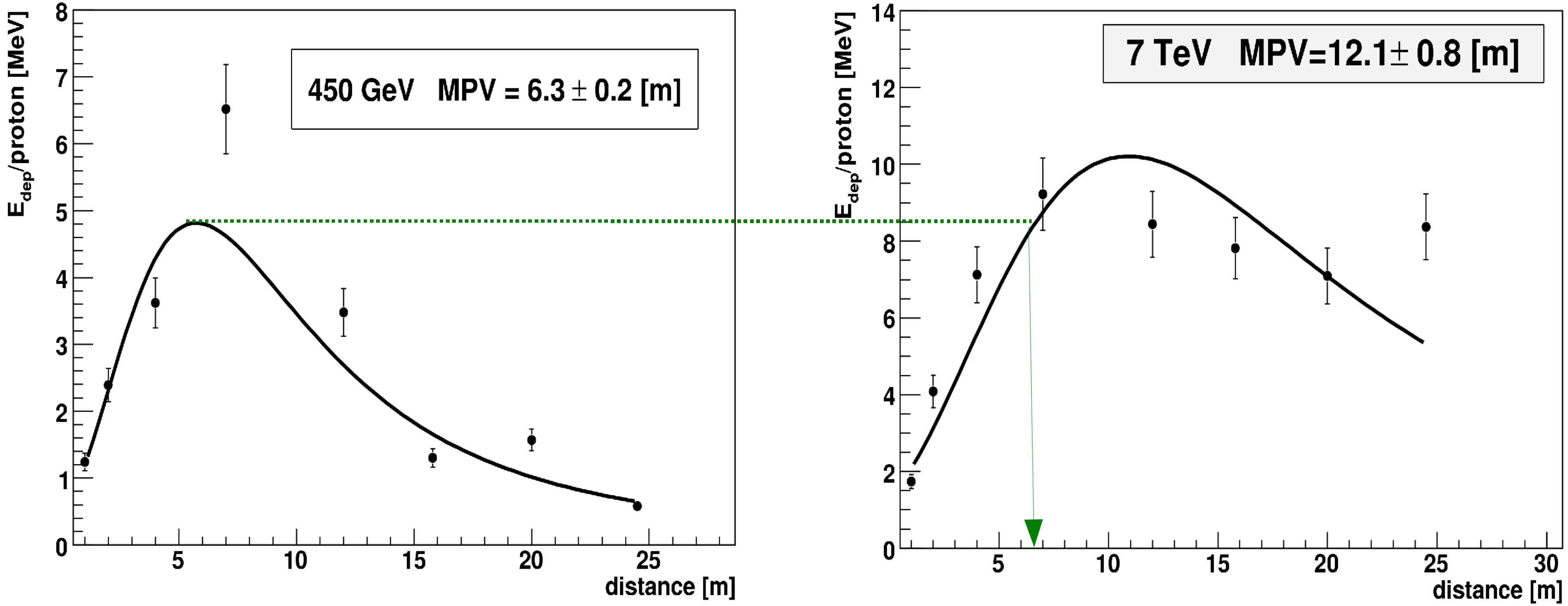
Statistics

- Various Monte Carlo samples were generated (Geant4.8.1)
- Interaction efficiency (p-wire) is about $1.32 \cdot 10^{-4}$ (among 8000 protons passing the wire center 1 interacts)
- Typical sample 300 – 400 events, simulation time about 20min/event (on P4 3 Ghz dual core)
- lxbatch was also extensively used

Placement of scintillators

Particles scattered by Wire Scanner are measured by scintillators (box 10x10x1 cm) placed next to beam pipe,

energy deposited in scintillators per interacting proton is:

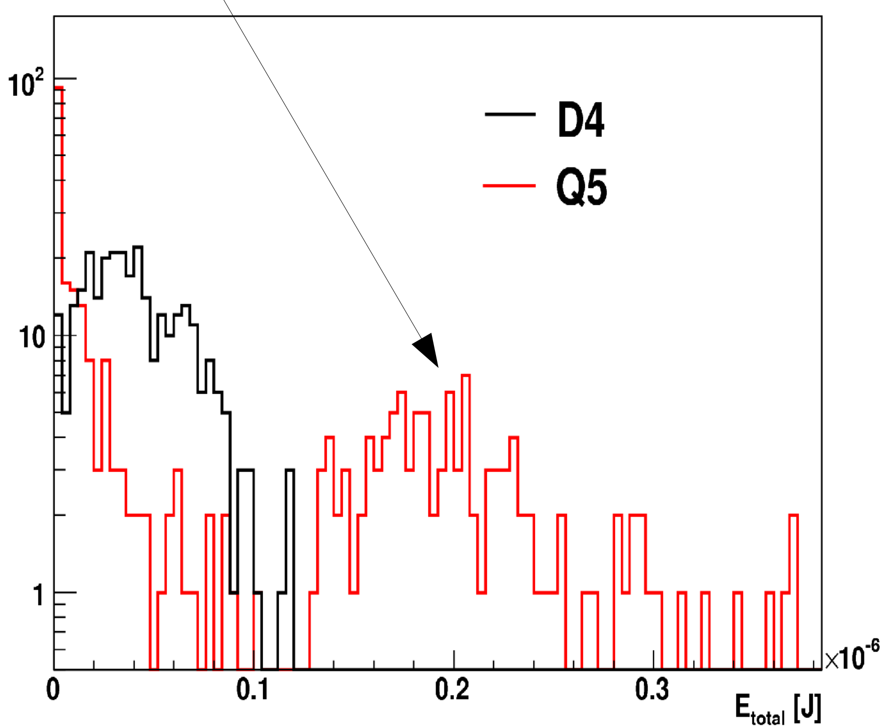


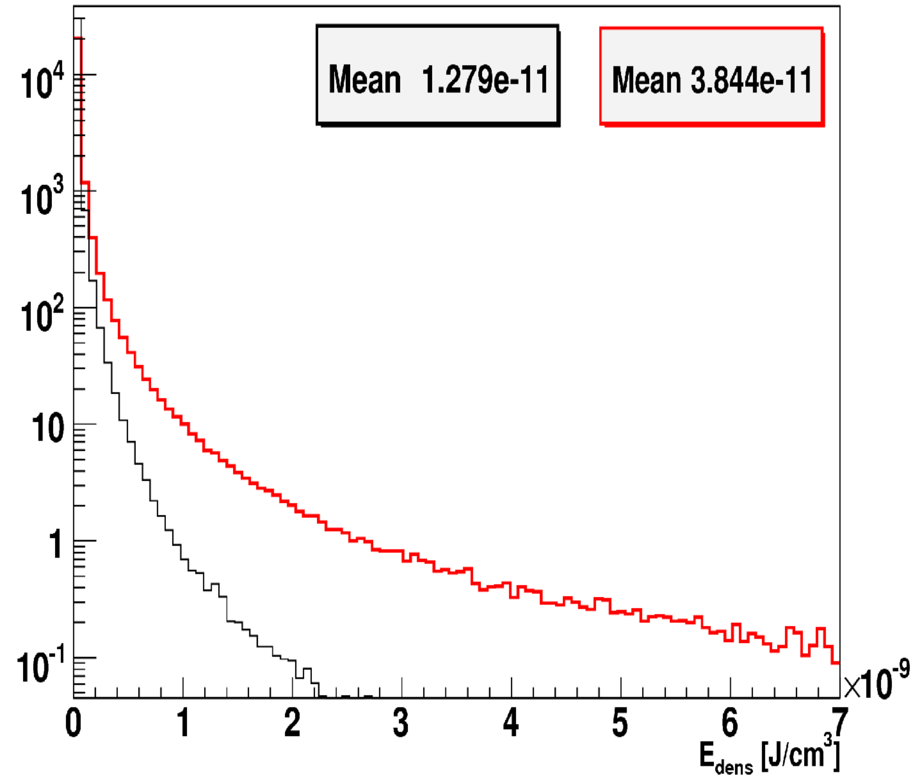
Signal in PMT scales with energy deposited in scintillators – there is a lot of signal at nominal luminosity – maximum 6-12 meters from WS, the signal level at 6 meters does not change with energy!

Coils: total energy depositions

Q5: there are events with large energy depositions

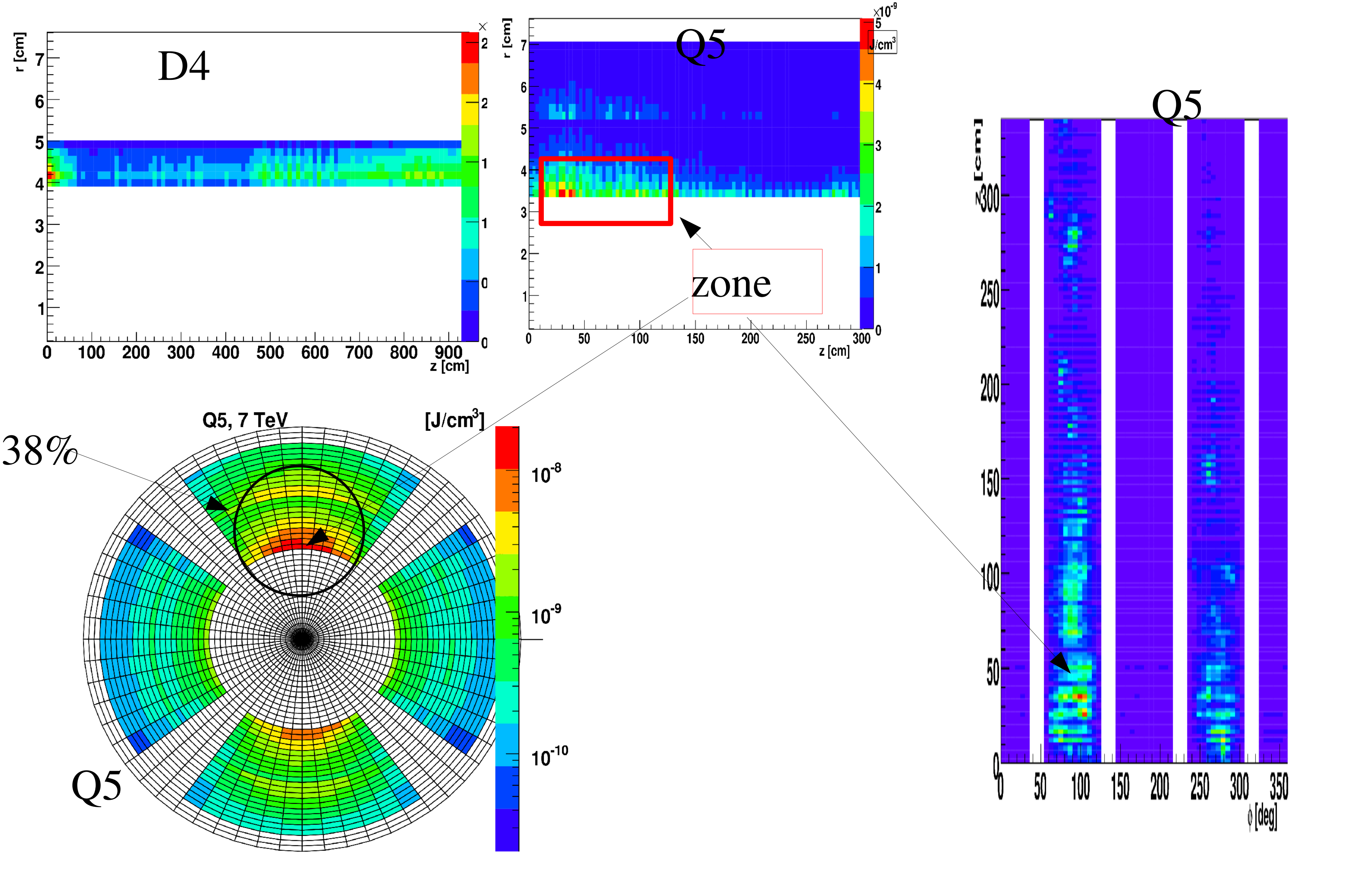
The average energy density is larger in Q5





Q5 is a problem!

Events geometry (in coils)



Cascades in coils

- Superconducting coil quenches if a local temperature raises above quench temperature
- Local temperature depends on the local deposited energy density; for Q5 coil at 7 TeV ρ=4.95 mJ/cm^3 is the assumed quench threshold
  (loss duration 0.3 ms, only cable entalphy used)
- It is crucial to chose correctly the volumes V in which energy deposits are measured $\rho = E_{dep}/V$

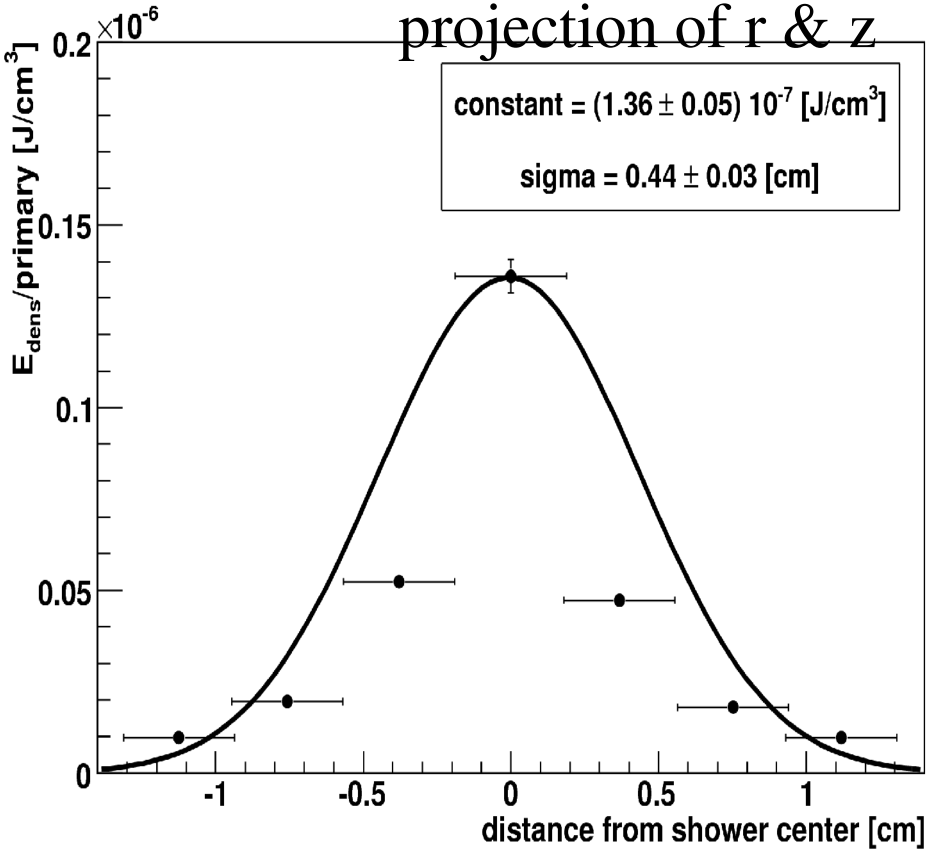
(overestimated V $\mapsto$ underestimated ρ,
underestimated V $\mapsto$ computing problems)

Choice of the volume

Volume size should be tuned to the shape of the shower.

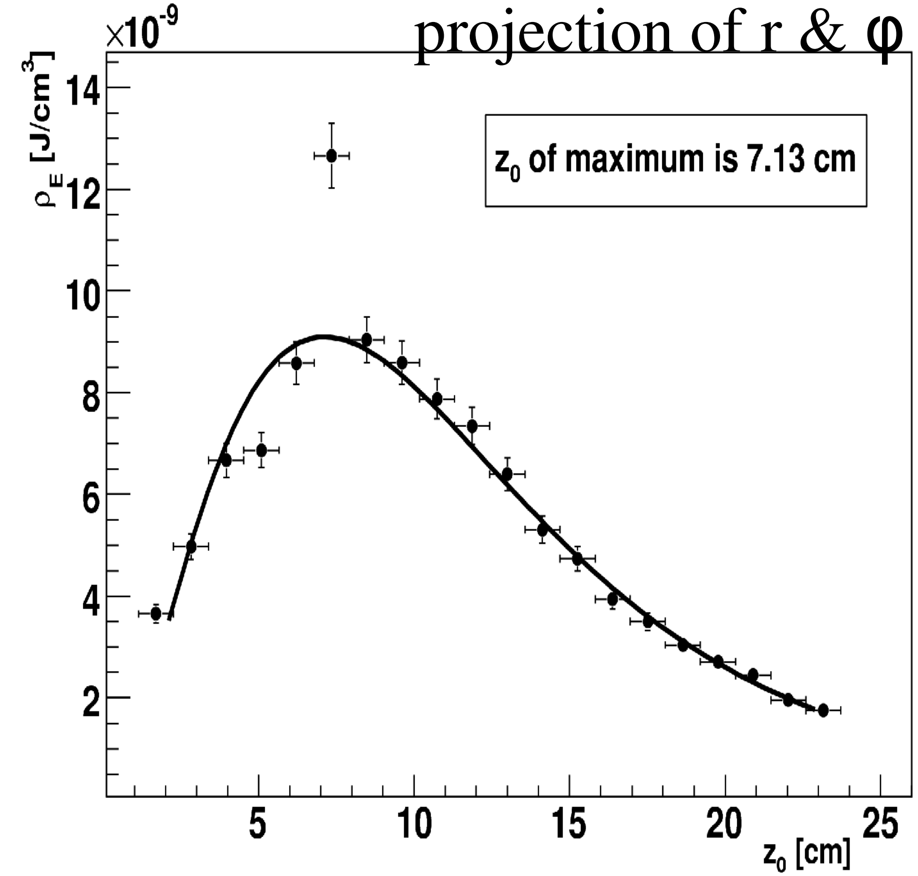
Average cascade measured around a hit with the highest ρ:

projection of r & z



Sum of gaussians

projection of r & φ



$$\rho = k[wt^{a-1}\exp(-bt)+(1-w)l^{c-1}\exp(-dl)]$$

w-"electromagneticity" of the cascade

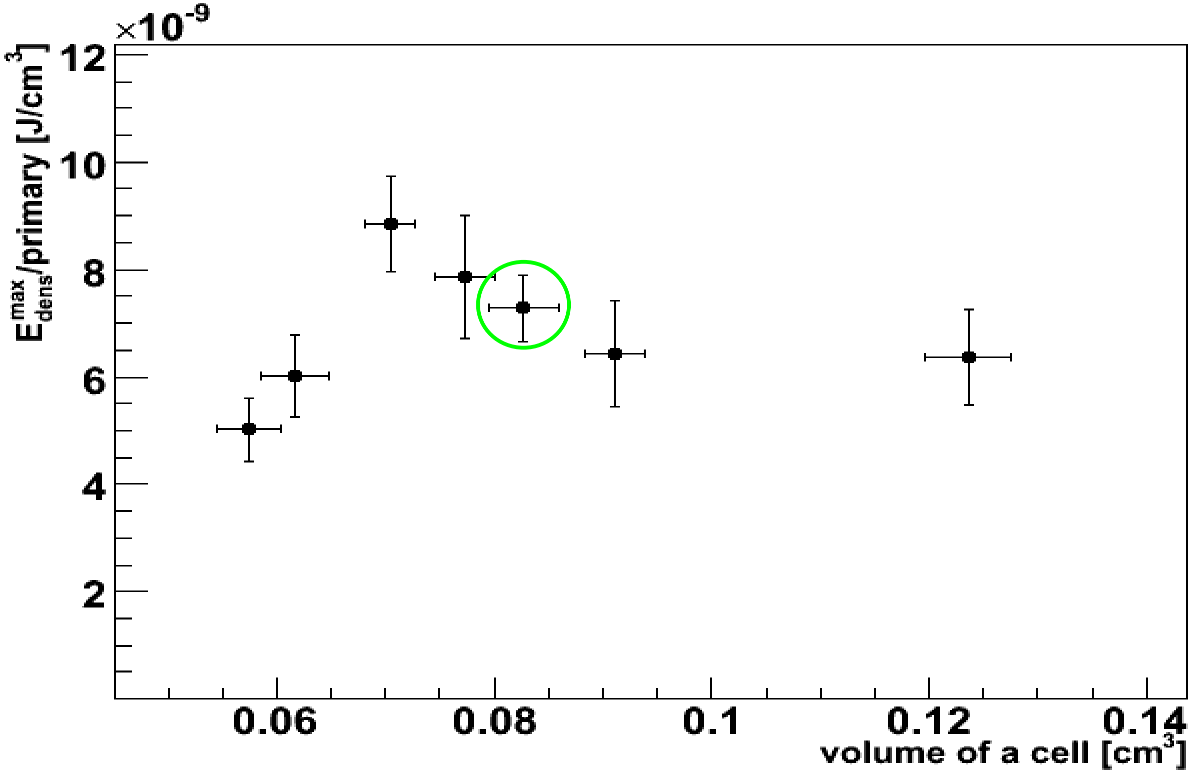
Choice of the volume (II)

Q5 cell volume has been altered (only in z-direction)

Variations of maximal energy density are not critical,

Slow increase of the energy density with decrease of the volumes is observed down to 0.05 cm^3

Standard range cut used in Geant4 (<1mm)



Maximal energy density - the method

- We suffer from small statistics

  (how to conclude about 10^{10} events having sample of 400)
- Define the most “hot” region of the coil (zone)
- Find probability distribution for a cell in the zone to reach a given energy density
- Use the parametrized probability to estimate how many protons are needed to deposit critical energy in magnet coil

“Hot” zone

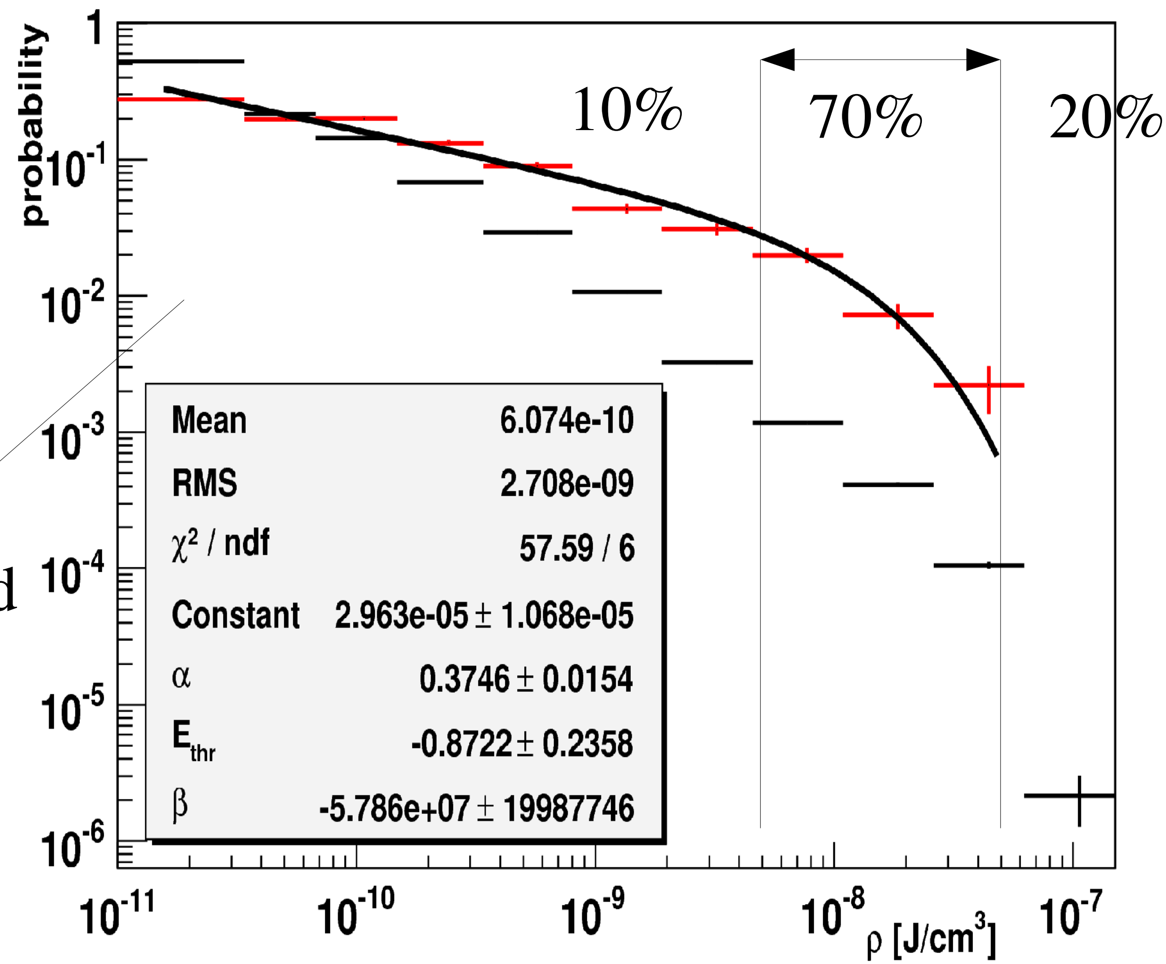
The “hot” zone is:

- $10 < z < 40$ cm
- $78^\circ < \varphi < 102^\circ$
- $\rho < 3.687$ cm

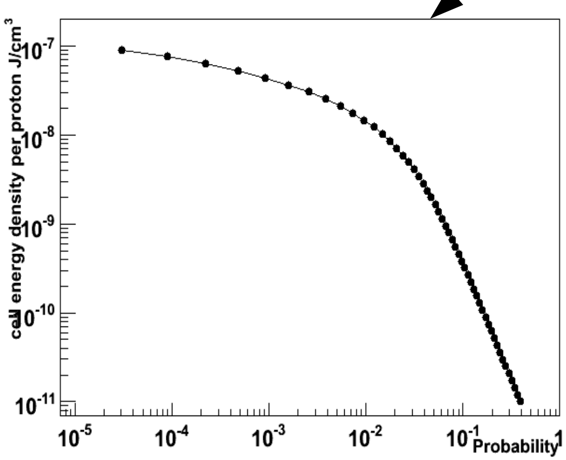
(variations were tested)

$$P(\rho)=\text{Constant}\cdot\rho^{-\alpha}\cdot\exp^{\beta}(\rho/\rho_{thr})$$

exponential cutoff at 0.87 J/cm^3



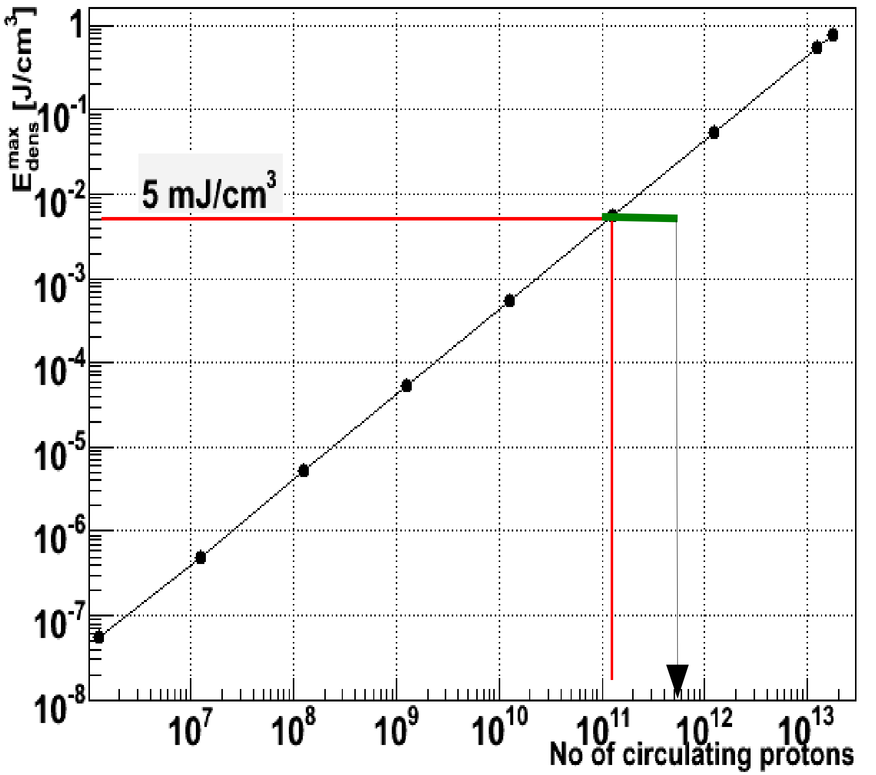
inversed



Maximal beam intensity

convert the probability per interacting proton into maximal beam intensity, assuming:

- V_{wire}=1m/s
- Σ_x=0.16 mm (3σ beam)
- t_{scan}=0.48 ms
- N^p_{LHC}=3.2 ·10^{14} protons
- ε=1.3 ·10^{-4} interaction efficiency (cross section)

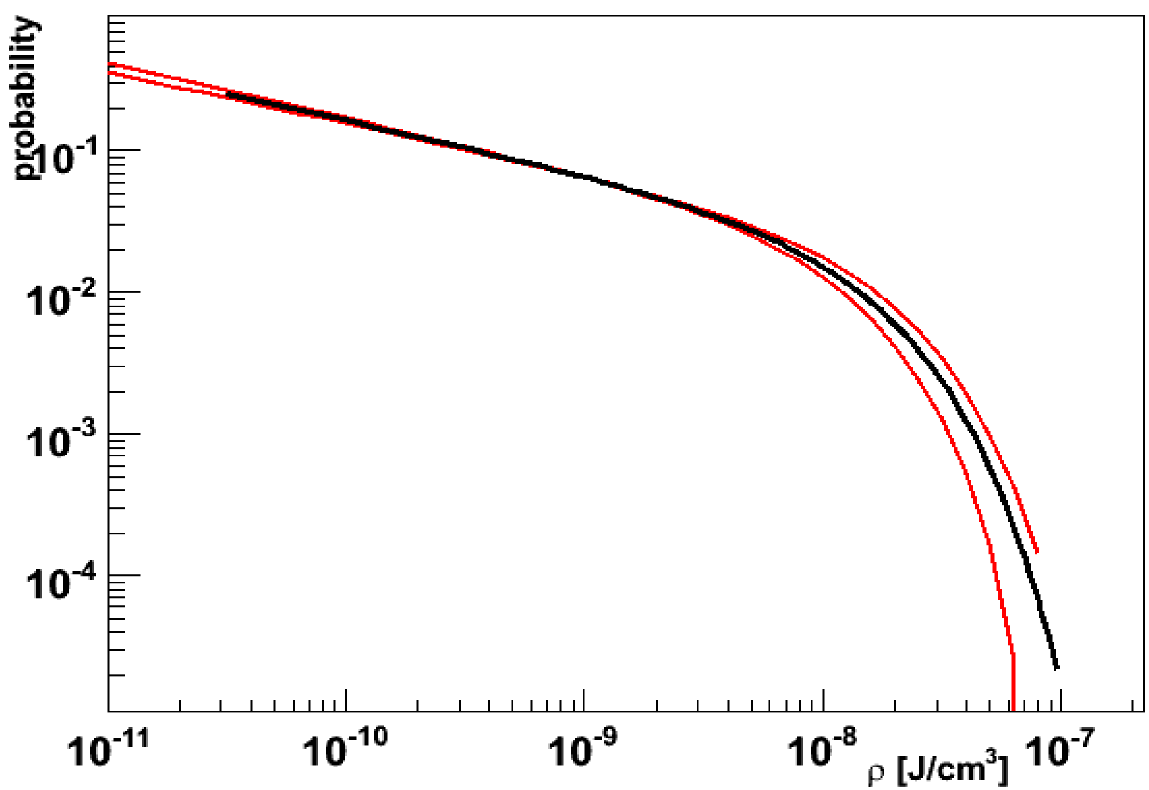


1-6·10^{11}

central value 1.1

Accuracy of simulation

- Details of geometry seems not to be crucial, although they can change the results by a factor of a few
- The method (used due to statistical limitations) – accuracy roughly estimated (by varying the “zone” and the fit parameters) to be around 50%
- Bin size 20%



Potential gains

Approximation	Estimated factor	Number of circulating protons	Optimistic
Initial		1.00E+011	6.00E+011
Wire movement	0.5	2.00E+011	1.20E+012
Wire shape	0.8	2.50E+011	1.50E+012
Magnetic field			
Inside coils	0.5	5.00E+011	3.00E+012
Shottky	0.5	1.00E+012	6.00E+012

Nominal beam: 3.2E+14, ie.

Wire Scanner should not quench the magnet up to 0.3-1.9% of the nominal beam (at 7 TeV).

Conclusions

- The Q5 magnet is critical – it is more fragile and cannot be shielded – particles are hitting from the beam pipe.
- Wire scanner can run up to $1\text{-}6\cdot10^{12}$ protons in the circulating beam, ie. about 0.3-2% of the nominal intensity at 7 TeV
- What could be do: faster scanner, thinner wire (there is plenty of signal in scintillators – it can be reduced without loosing accuracy)
- Additional error of the estimation of the maximal beam current is about 50% (0.15-3% of the nominal intensity)